Chapter 1
Introduction

Background

This report provides an integrated approach to manage the solids generated in urban wet weather flows (WWFs), both on the land surface and in drainage sewer systems. Threats to the quality of receiving waters by discharges from urban-storm-generated WWF, including combined sewer overflow (CSO) and polluted runoff from urban streets, are well known. During many storm events, large volumes of stormwater are drained via street inlets into the urban sewer system. The storm runoff washes off street dust-and-dirt and pollutants from catchment surfaces into the sewer system. Furthermore, the unsteady-state storm inflow resuspends sewer sediment that has settled in the sewer bottom, causing it to be transported downstream. Recently, researchers reported that sewer sediment deposited from prior storms contributed a significant amount of pollutants into receiving waters. This often creates a highly concentrated pollutant load. In most cases, CSO carries resuspended sewer sediment and generates a highly concentrated pollutant load sometimes associated with the "first-flush" phenomenon (Saget et al., 1996; Arthur and Ashley, 1998; Krebs et al., 1999). In most cases, CSO carries this resuspended sewer sediment into local waterways. Sewer sediment deposited during dry weather flow (DWF) contributes between 30% to 80% of pollutants into receiving waters (Ahyerre et. al., 2001).

The Problem

One of the underlying reasons so much sediment is deposited in combined sewers is hydraulic design. Combined sewers are sized to convey many times the anticipated peak DWF; they can carry up to 1,000 times the expected background DWF. Ratios of peak to average DWF usually range from 2 to 10 for interceptor sewers. The oversized and mildly sloping combined sewer segments possess a substantial potential for sedimentation during dry weather periods. DWF velocities are typically inadequate to maintain settleable solids in suspension and a substantial amount of sewer solids accumulated in the pipes. During rain storms, the accumulated solids may resuspend, because of the limited hydraulic capacity of the interceptor sewers, overflow to receiving waters. Suspended solids (SS) concentrations of several thousand parts per million are common for CSOs. This can produce shock loadings detrimental to receiving waters. Accumulation of sewer solids in sewers also result in a loss of flow-carrying capacity that may restrict/block flow and cause an upstream surcharge, local flooding, and enhanced solids deposition. Sewer-solid accumulation in urban drainage systems also creates septic conditions that pose odor, health hazards, and corrosion problems.

During low-flow periods, sanitary wastewater solids deposit in combined sewers because the flow velocity is usually less than the particle-settling velocity. Estimates of solids deposition range from 5% to 30% of the daily SS pollution loading (Pisano et al., 1998). The average dry period between storm events is about four days for many areas of the United States, especially along the eastern seaboard. If 25% of the daily pollution loading accumulates in the collection system, an intense rainstorm causing a two hour CSO, after four days of antecedent dry weather, will wash the equivalent of one-day's flow of raw-sanitary wastewater to the receiving waters. In Europe, average deposition rates have been measured to range from 30 to 500 g/m/d (Ashley and Crabtree, 1992). Even sewers supposedly designed to be 'self-cleansing' will have transient sediment deposits, and part of the load in transport will move near the bed (May et al., 1996). Furthermore, a one-day equivalent of raw-sanitary wastewater, discharged within a two-hour period, is twelve times the rate at which raw-sanitary wastewater enters the collection system.

Sewer sediments contain high concentrations of pollutants (80,000 mg/L of BOD_5; 200,000 mg/L of COD; and 200 mg/L of NH_3-N) (Arthur et al., 1996). As storm-flow intensities increase, resuspension of sewer sediment will occur. In combined sewers this occurs when they hydraulically overload and discharge as CSOs. The sewer-sediment layer contains organic materials and sulfides that can generate toxic, corrosive, and hazardous gases (e.g., hydrogen sulfide (H_2S) and methane, under anoxic conditions). Sulfates are reduced to H_2S and then oxidized to sulfuric acid by biochemical transformation; the acid attacks the sewer, thereby weakening its structural integrity. Extensive corrosion of concrete and their reinforcing bars results in cracks and infiltration and exfiltration of raw wastewater, causing overflow and WWTP overloading and groundwater contamination, respectively. Thus, control of sewer sediment not only protects urban receiving-water quality it also prevents hazardous conditions in sewerage systems and maintains the structural integrity of the sewer.

One of the challenges in protecting urban waterways lies in effectively managing contaminated sediments in both the sewer system and the receiving water. To enable urban communities to develop better plans to reduce the risks associated with WWF, research is needed to develop tools for a better understanding and assessment of the fate and transport of sediment solids and associated pollutants.

This report serves as a reference for the user community faced with the challenges to combat urban wet-weather-induced point and diffused sources of water pollution. It covers the gamut of engineering requirements, from pollution problem assessment tools for both desktop analysis and field investigation to determine extended problems of sewer sediment. It includes the following six chapters:

- Sources of sewer sediment and impacts (Chapter 2)
- Estimation of urban watershed solids loading (Chapter 3)
- Methodology for quantifying sediment-solids in sewer system (Chapter 4)
- Methods for field sampling and monitoring of hydrogen sulfide in sewer (Chapter 5)
- Sewer sediment control: sewer flushing (Chapter 6)
- A case study of sewer flushing system design and operation (Chapter 7)

The sewer sediment solids and associated pollutants found in combined sewers are mainly resulted from sanitary wastewater solids deposition during dry weather. These solids account for the majority of WWF pollution. All sources of WWF pollutants and their impacts are explained in Chapter 2. Methods for estimating solids that are washed-off from land surface during a storm event are presented in Chapter 3. A set of generalized procedures for estimating pollutant loadings associated with dry weather wastewater solids deposition in combined sewer systems is described in Chapter 4. Once the sewer segments most prone to sewer sedimentation are identified, sediment sampling is needed to determine actual sewer sediment and sedimentation characteristics. Chapter 5 describes sampling and monitoring procedures for measuring both the gas phase and dissolve phase of H_2S concentrations.

In order to reduce solids and associated pollutants entering in sewer systems, one must start with pollution prevention and source control by the best management practices (BMPs). Information on the urban stormwater BMPs implementation and evaluation are available in published literatures (ASCE, 2001; USEPA, 2002; Strecker et al., 2001; Strecker, 2002). Thus, Chapter 6 addresses only the management practices for in-sewer sediment solids control. The last chapter, Chapter 7 - Sewer Sediment Flushing, brings together information on the most recent case in planning and implementing in-sewer sediment control technologies in a large urban sewer-catchment. In this chapter, also includes estimated operation and maintenance costs as well as capital costs based on the Engineering News Record (ENR) Construction Cost Index of 6389 as of August 2001.